Nuclear Physics

Question paper 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Particle & Nuclear Physics
Sub Topic	Nuclear Physics
Paper Type	Theory
Booklet	Question paper 1

Time Allowed: **72 minutes**

Score: **/60**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 A nuclear reaction between two helium nuclei produces a second isotope of helium, two protons and 13.8 MeV of energy. The reaction is represented by the following equation.

$$^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{He} + 2\,{}^{\cdots\cdots}_{\cdots\cdots}\text{p} + 13.8\,\text{MeV}$$

(a) Complete the nuclear equation. [2]

(b) By reference to this reaction, explain the meaning of the term *isotope*.

.....

.....

.....[2]

(c) State the quantities that are conserved in this nuclear reaction.

.....

.....

.....

.....

.....[2]

(d) Radiation is produced in this nuclear reaction.

State

(i) a possible type of radiation that may be produced,

.....[1]

(ii) why the energy of this radiation is less than the 13.8 MeV given in the equation.

.....[1]

(e) Calculate the minimum number of these reactions needed per second to produce power of 60 W.

number = ... s^{-1} [2]

2 **(a)** A nuclear reaction occurs when a uranium-235 nucleus absorbs a neutron. The reaction may be represented by the equation:

$$^{235}_{92}U + {}^{W}_{X}n \rightarrow {}^{93}_{37}Rb + {}^{141}_{Z}Cs + Y{}^{W}_{X}n$$

State the number represented by the letter

W .....

X .....

Y .....

Z .....

[3]

(b) The sum of the masses on the left-hand side of the equation in **(a)** is not the same as the sum of the masses on the right-hand side.

Explain why mass seems not to be conserved.

.....

.....

.....[2]

3 **(a)** Uranium (U) has at least fourteen isotopes.
Explain what is meant by *isotopes*.

.....

.....

..... [2]

(b) One possible nuclear reaction involving uranium is

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{Z}\text{Kr} + x\,{}^{1}_{0}\text{n} + \text{energy.}$$

(i) State three quantities that are conserved in a nuclear reaction.

1. .....

.....

2. .....

.....

3. .....

.....
[3]

(ii) For this reaction, determine the value of

1. Z,

Z = ... [1]

2. x.

x = ... [1]

4 **(a)** Explain what is meant by *radioactive decay*.

.....

.....

..... [2]

(b) **(i)** State how the random nature of radioactive decay may be inferred from observations of the count rate.

.....

..... [1]

(ii) A radioactive source has a long half-life so that, over a period of several days, its rate of decay remains constant.
State the effect, if any, of a rise in temperature on this decay rate.

..... [1]

(iii) Suggest why some radioactive sources are found to contain traces of helium gas.

.....

.....

..... [2]

5 Tungsten-184 ($^{184}_{74}W$) and tungsten-185 ($^{185}_{74}W$) are two isotopes of tungsten.

Tungsten-184 is stable but tungsten-185 undergoes β-decay to form rhenium (Re).

(a) Explain what is meant by *isotopes*.

.....

.....

.....

..... [2]

(b) The β-decay of nuclei of tungsten-185 is spontaneous and random.

State what is meant by

(i) *spontaneous* decay,

.....

..... [1]

(ii) *random* decay.

.....

..... [1]

(c) Complete the nuclear equation for the β-decay of a tungsten-185 nucleus.

$^{185}_{74}W \rightarrow$ ..... + ... [2]

6 The spontaneous and random decay of a radioactive substance involves the emission of either α-radiation or β-radiation and/or γ-radiation.

(a) Explain what is meant by *spontaneous* decay.

.....

.....

..... [2]

(b) State the type of emission, one in each case, that

(i) is not affected by electric and magnetic fields,

..... [1]

(ii) produces the greatest density of ionisation in a medium,

..... [1]

(iii) does not directly result in a change in the proton number of the nucleus,

..... [1]

(iv) has a range of energies, rather than discrete values.

..... [1]

7 Thoron is a radioactive gas. The variation with time t of the detected count rate C from a sample of the gas is shown in Fig. 8.1.

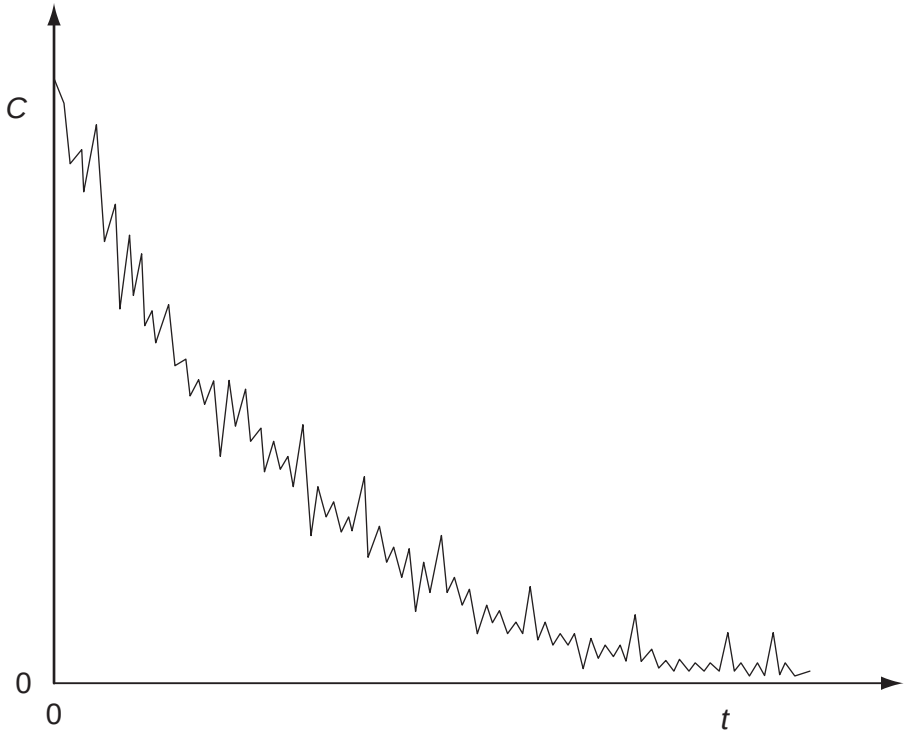

Fig. 8.1

Radioactive decay is said to be a random and spontaneous process.

(a) Explain, by reference to radioactive decay, what is meant by a *random* process.

.....

.....

..... [2]

(b) State the feature of Fig. 8.1 which indicates that the process is

(i) a decay process,

..... [1]

(ii) random.

..... [1]

(c) A second similar sample of thoron is prepared but it is at a much higher temperature. The variation with time of the count rate for this second sample is determined.
State the feature of the decay curves for the two samples that suggests that radioactive decay is a spontaneous process.

.....

..... [1]

8 The radioactive decay of nuclei is both spontaneous and random.

Explain what is meant by

(a) *radioactive decay* of a nucleus,

.....

.....

..... [2]

(b) *spontaneous* decay,

.....

.....

..... [2]

(c) *random* decay.

.....

.....

..... [2]

9 Fig. 8.1 shows the position of Neptunium-231 ($^{231}_{93}$Np) on a diagram in which nucleon number (mass number) *A* is plotted against proton number (atomic number) *Z*.

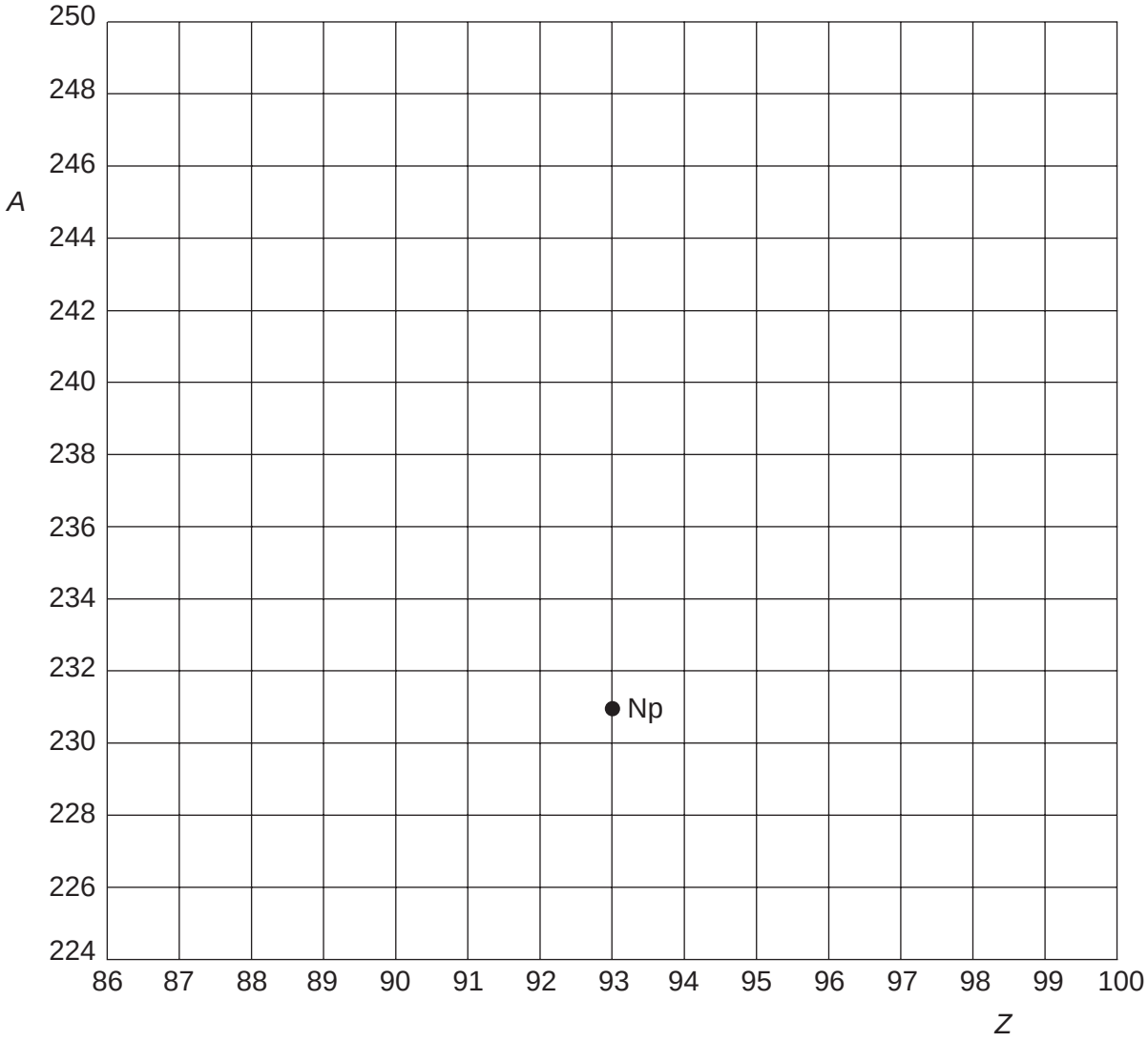

Fig. 8.1

(a) Neptunium-231 decays by the emission of an α-particle to form protactinium.
On Fig. 8.1, mark with the symbol Pa the position of the isotope of protactinium produced in this decay. [1]

(b) Plutonium-243 ($^{243}_{94}$Pu) decays by the emission of a β-particle (an electron).
On Fig. 8.1, show this decay by labelling the position of Plutonium-243 as Pu and the position of the daughter product as D. [2]

10 (a) A student is provided with a freshly prepared sample of a radioactive material and the count rate Cfrom the source is found to vary with time tas shown i, Fig. 6.1 (a).

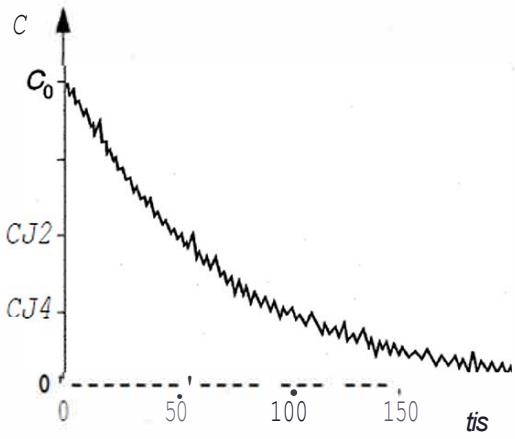

Fig. 6.1 (a)

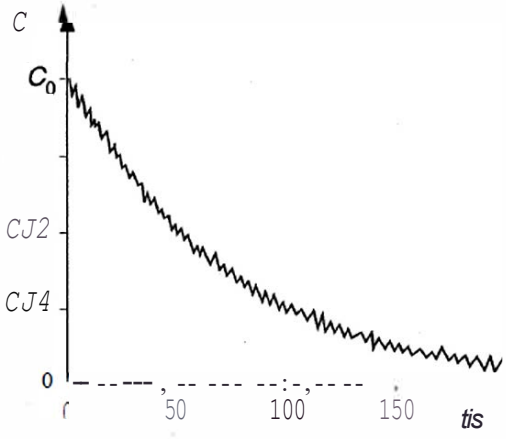

Fig. 6.1 (b)

A second similar sample of the radioactive material is then prepared and the student repeats the experiment, but with the sample at a higher temperature. The variation with time of the count rate for the second sample is shown i1 Fig. 6.1 (b).

State the evidence that is provided by these two experiments for

Q) the random nature of radioactive decay,

.....

.....

(ii) the spontaneous nature of radioactive decay.

.....

.....

[2]

(b) The radioactive source i, (a) is an isotope of radon (^{2} Rn) that emits a-radiation to become polonium (Po).

(I) State the number of neutrons i, one nudeus of radon-220.

number = ... (1)

(ii) Write down a nuclear equation to represent the radioactive decay of a nucleus of radon.

....

$^{220}_{86}Rn$ ◆ Po + ...

....

(3)